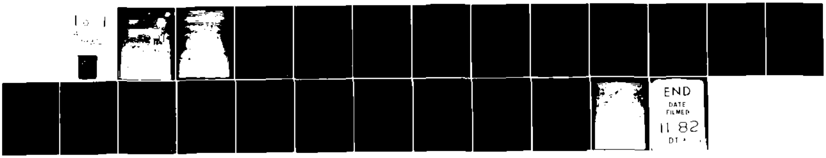
AD-A119 922 ROME AIR DEVELOPMENT CENTER GRIFFISS AFB NY F/G 17/9
ERROR SOURCES IN MEASUREMENTS OF LARGE-APERTURE SPACE-BASED RAD--ETC(U)
MAY 82 R L HAUPT, M J O'BRIEN
UNCLASSIFIED RADC-TR-82-118 NL



AD A119922

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RADC-TR-82-118	2. GOVT ACCESSION NO. AD-A119922	3. RECIPIENT'S CATALOG NUMBER 82-181
4. TITLE (and Subtitle) ERROR SOURCES IN MEASUREMENTS OF LARGE-APERTURE SPACE-BASED RADAR ANTENNAS		5. TYPE OF REPORT & PERIOD COVERED In-House
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Randy L. Haupt, 1Lt, USAF Michael J. O'Brien, Major, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Deputy for Electronic Technology (RADC/EEC) Hanscom AFB Massachusetts 01731		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62702F 46001507
11. CONTROLLING OFFICE NAME AND ADDRESS Deputy for Electronic Technology (RADC/EEC) Hanscom AFB Massachusetts 01731		12. REPORT DATE May 1982
		13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Randy L. Haupt, 1Lt, USAF, RADC/EEC

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Space-Based Radar
Radiation Patterns
Radar
Antenna

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The sources of errors associated with measuring the radiation pattern of a space-deployable radar antenna are examined. The specifications for the Space-Based Radar require a lightweight, fragile antenna with a large aperture and low sidelobes. These three requirements place severe constraints on both the testing environment and the measurement equipment. Applicable sources of errors were presented for both farfield and nearfield measurement techniques.

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1. INTRODUCTION

Recent technological advances have made the Space-Based Radar (SBR) a realistic tool for scientific research and military defense. Some of its possible uses are:

- Ocean Surveillance
- Conus Air Defense
- Naval Fleet Defense
- Theatre Support
- Space Defense
- Mapping of the earth's surface
- Air traffic control
- Coastal surveillance

Millions of dollars from several different government agencies and private companies have gone into research and development on Space-Based Radars (SBRs). With this type of support and interest, there may be several SBRs orbiting the earth before the close of this century.

Such an expensive high-performance antenna should be tested accurately prior to deployment in space. Since little repair and maintenance can be done

Received for publication 6 May 1982

once the antenna is in orbit, measuring the antenna pattern on the ground is necessary to provide important information about the antenna's performance in space. The antenna pattern reveals whether the sidelobe level, gain, and polarization meet required specifications. An unsatisfactory antenna pattern indicates problems in the design, antenna components, or in the measuring facility. In such a case, the antenna will be kept on the ground for further testing and repairs.

There are two main reasons for writing this report. The first is to delineate the problems of experimentally verifying the electromagnetic properties of large-aperture, high-performance, space-deployable antennas. The second is to present possible solutions to these problems, and stimulate additional interest. The ultimate goal is to be able to perform these experiments prior to the actual space deployment.

The first part of the report outlines the problem, and discusses antenna pattern measurements in general. After the measurement background, the report examines errors due to farfield measurements, then considers nearfield errors. Many of the errors are common to both types of measurements. A discussion on error effects on antenna patterns concludes the report.

2. THE PROBLEM

Several of the proposed SBRs can be measured on existing antenna pattern ranges. Military applications, however, complicate the problem by requiring a large-aperture SBR antenna with high-performance characteristics. The large aperture provides a large gain and narrow main beam for detection and tracking of enemy aircraft. A synthetic aperture is not suitable because of the long processing time and high target velocities. The high-performance characteristics entail low sidelobes and deep adaptive nulls. Enemy jammers and ground clutter force these strict high-performance characteristics on the antenna. As a result, the military SBRs require special measurement facilities that do not exist at this time.

This report concerns only SBR antennas with very large apertures (>100 wavelengths) and low sidelobes (<40 dB rms). No attempt is made to use any specific example of the many possible antenna designs for the SBR. The antenna may be a reflector, a phase array, or a space-fed lens. The measurement tolerances are common to any antenna, because the aperture size and performance characteristics remain the same; therefore, the design will remain as generic as possible.

There are three major features of the SBR that make the measurement problem particularly difficult. First, a large aperture requires a large measurement

range. A bigger range costs more money, and is harder to build within the scattering and mechanical tolerances required. A second problem pertains to meeting the environmental and scattering constraints imposed by the low sidelobes. Scattering, weather, and outside interference cause phase and amplitude errors that induce measurement errors. Finally, a space-deployable antenna requires special handling and monitoring techniques. The antenna is very lightweight and has minimal support, so gravity hampers any attempt to move or construct the antenna on earth.

An antenna with only one of the above features is difficult to measure accurately. Combining these three characteristics into one antenna magnifies the problem considerably. This type of antenna has never been built before. A small space-deployable antenna may be easy to support, but a 50 m diameter one is not. A large, fragile antenna needs large, rigid supports. The extensive supporting structures, in turn, produce additional scattering. Solving one problem, that is, support, magnifies another problem, scattering. The error tolerances for testing the SBR designed for military applications are strict, and difficult to meet.

3. BACKGROUND ON MEASURFMENTS

The complete radiation pattern of an antenna can be determined from the knowledge of the magnitude and phase of its radiated field in two orthogonal polarizations. The more accurately the phase and magnitude are known, the more accurately the antenna pattern can be predicted. Such measurements on a large space-based radar will involve considerable cost. In order to justify this cost, it is imperative to know if the measurement procedure can determine the pattern to within an acceptable error.

Four types of electric field measurements of particular interest are amplitude, phase, gain, and polarization. In general, both amplitude and phase measurements are required to determine the radiation pattern. Measurements made in the far-field, however, only require knowledge of the field amplitude to determine the pattern. Another important measurement is gain. The gain of the antenna determines its sensitivity to receive signals. It is defined as the maximum radiation intensity divided by the average radiation intensity. The gain is found by comparing the test antenna's pattern to the antenna pattern of a standard gain antenna. Finally, polarization measurements test designed polarization characteristics.

The above measurements are made on some type of antenna range with an auxiliary antenna. This range is not ideal; hence, it will introduce measurement errors. The degree of acceptable errors is a function of the required accuracy of the measurement. In this case, the antenna range must be suitable for

measuring the space-based radar antenna, which has low sidelobes, deep nulls, and a large aperture. The range also needs special antenna mounts to hold and move the space-deployable antenna.

Testing the space-built antenna in a gravitational environment induces errors. Mounting and moving the antenna are difficult tasks. The gravitational forces that are negligible in the space environment will deform the structure during testing on earth, thus creating severe errors. Even a slight deformation can create severe errors in low sidelobes.

Some of the measurement errors are due to the measurement equipment; others, such as scattering errors, are due to the testing environment; still others are caused by the position of the test antenna and/or an auxiliary antenna. Limiting these errors to a tolerable level requires considerable cost and engineering effort. Normally, the equipment and environment do not need the stringent specifications required to measure the SBR antenna pattern.

4. ERRORS IN FARFIELD MEASUREMENT

When performing any experiment, one desires to simplify the procedure without jeopardizing the results. Recall that to generate a farfield pattern, both phase and amplitude of the electric field are needed. Phase is a difficult measurement to make compared to amplitude. An attractive simplification of the electric field measurements is to measure only the amplitude. This simplification is only possible when the test and source antennas are separated by a large enough distance. The technique is called farfield measurement.

A farfield measurement range usually uses the test antenna as the receiving antenna, and the auxiliary antenna as the source. The farther the two antennas are separated, the more accurately the pattern is measured. On the other hand, the closer the two antennas, the less real estate needed for the range, and the less the environmental effects. This situation presents a dilemma. The optimum distance is the closest distance at which the pattern errors are acceptable. This distance depends upon the size, type, and performance characteristics of the test antenna.

Farfield measurements are only attractive if they do not jeopardize the results. Of course, the simplification induces errors. It is important, therefore, to know when these errors significantly distort the results, and what if anything can be done to reduce the errors to an acceptable level. In pursuit of these objectives, we shall direct our attention to determining these errors.

The first question to answer is "When is the separation between the source and test antenna far enough to allow only amplitude measurements?" The source

antenna is considered to be in the farfield of the test antenna when the energy from the source approximates a uniform plane wave across the aperture of the test antenna. If the source is a point source, then at a distance $R = 2D^2/\lambda$, the spherical waves emanating from the source differ from a plane wave by $\pi/8$ radians at the edges of the test aperture shown in Figure 1. For many antennas this $\pi/8$ phase

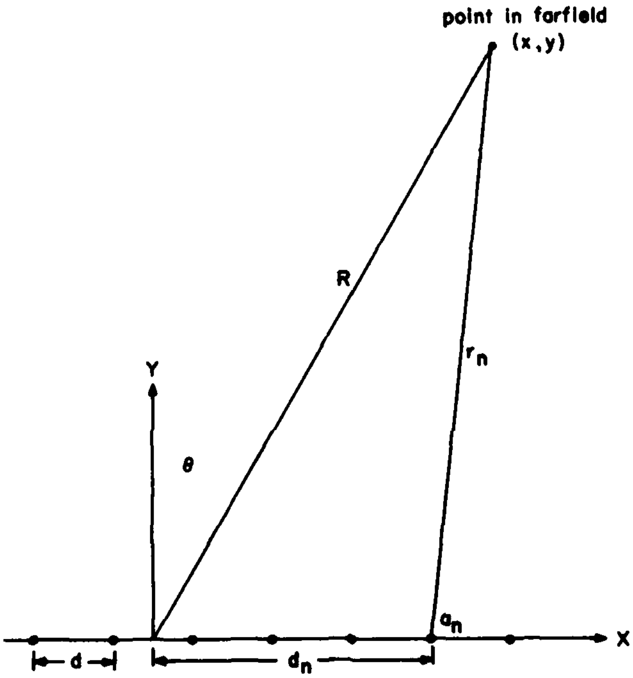


Figure 1. Phase Errors Due to Farfield Approximation

error is acceptable. However, the error will have a noticeable effect in the region near the main beam of a low sidelobe antenna. To observe this effect, consider the field of the linear array in Figure 2.

The farfield (F) of an N element linear array can be represented as

$$F = \sum_{n=1}^{N} a_n \frac{e^{-j\bar{K}\cdot\bar{r}_n}}{|\bar{r}_n|} \qquad (1)$$

an - amplitude weight of n^{th} element

$\bar{K}$ - propagation vector

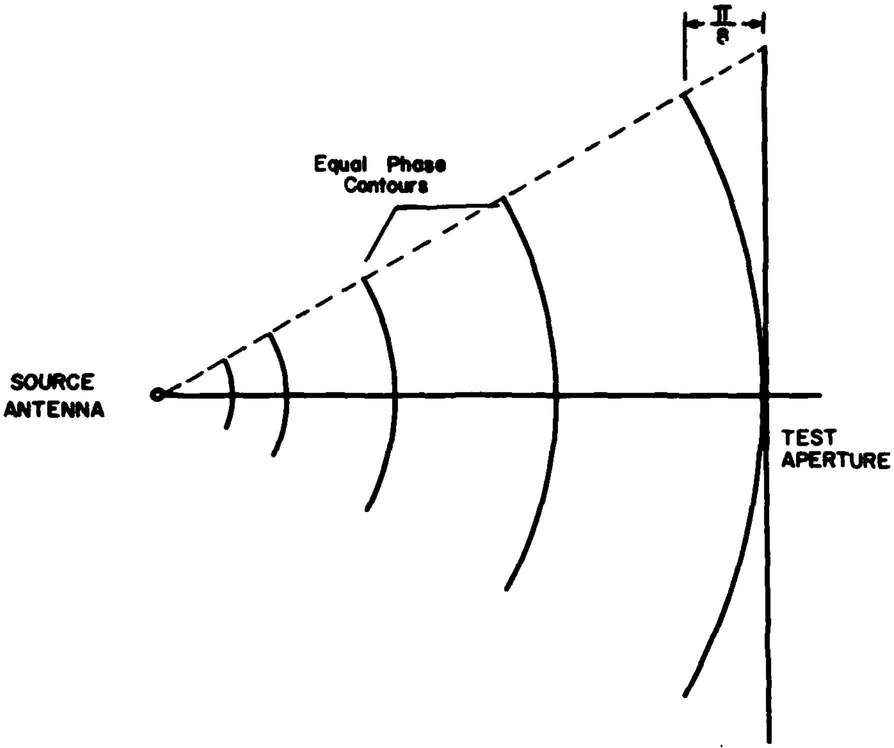


Figure 2. Geometry of a Linear Array

For R large, the farfield can be approximated by

$$F = \frac{1}{R} \sum_{n=1}^{N} a_n e^{-jk(d_n \sin\theta - d_n{}^2/2R)} \quad . \qquad (2)$$

In the true farfield, R approaches infinity resulting in

$$F = \frac{1}{R} \sum_{n=1}^{N} a_n e^{\, jkd_n \sin\theta} \quad . \qquad (3)$$

In practice, the measured field will be described more accurately by Eq. (2) than by Eq. (3). The quadratic phase error of $d_n^2/2R$ decreases as R increases. At $R=2D^2/\lambda$, this phase error at the edge of the aperture becomes

$$\frac{(2\pi/\lambda)(D/2)^2}{2 \times 2D^2/\lambda} = \frac{\pi}{8} \quad . \tag{4}$$

D - diameter of aperture

λ - wavelength

which is the same as shown in Figure 1. The quadratic phase error is more significant in the vicinity of the main beam where the sin term in the exponent of (2) is small. Therefore, it can have a deleterious effect on the measured pattern.

The significance of errors depends on the antenna under test. As an example, the patterns in Figures 3 and 4 show the effects of this error on a 40-element uniform array, and a 40-element 40 dB tapered Chebychev array. Note the error in the Chebychev pattern is concentrated near the main beam, and is more significant than the error in the uniform array pattern. The error effects, however, are spread over a wider angular region in the uniform array pattern than in the tapered pattern. This phenomenon can be explained easily by a simple approximation. Since $dn^2/2R$ is small, Eq. (2) can be written as:

$$\begin{aligned} F &= \frac{1}{R} \sum_{n=1}^{N} a_n e^{-jk\, d_n \sin\theta} \sum_{n=1}^{N} a_n e^{jk\, d_n^2/2R} \\ &= \frac{1}{R} \sum_{n=1}^{N} a_n e^{-jk\, d_n \sin\theta} \sum_{n=1}^{N} a_n (1+jk\, d_n^2/2R) \\ &= \frac{1}{R} \sum_{n=1}^{N} a_n e^{-jk\, d_n \sin\theta} + j \sum_{n=1}^{N} \frac{a_n k\, d_n^2}{2R} e^{-jkd_n \sin\theta} \end{aligned} \tag{5}$$

The first term is the true farfield pattern, and the second term is the pattern due to the phase error. For the uniform array error pattern, the element weights have a quadratic amplitude taper that results in a skinny main beam and high sidelobes. The phase error effects are distributed more throughout the measured pattern. For the Chebychev tapered array, however, the product of the Chebychev amplitude distribution and the quadratic error amplitude distribution produces an error pattern with a fat main beam and low sidelobes. The main beam of the error pattern significantly affects the region near the main beam of the measured

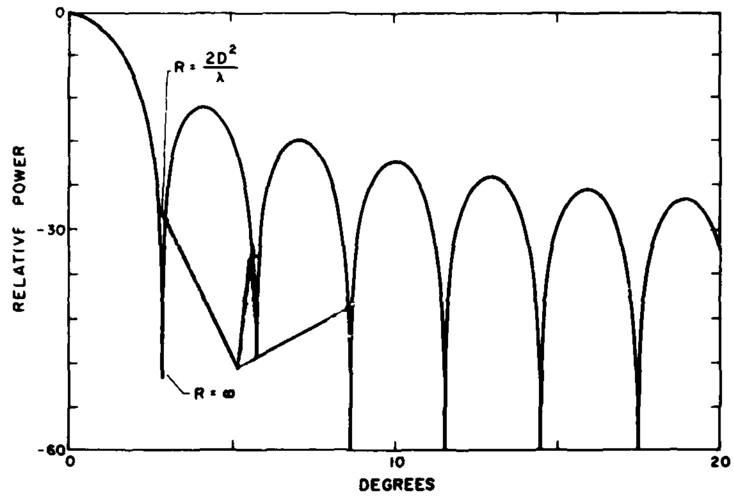


Figure 3. Farfield Approximation Error on Uniform Array

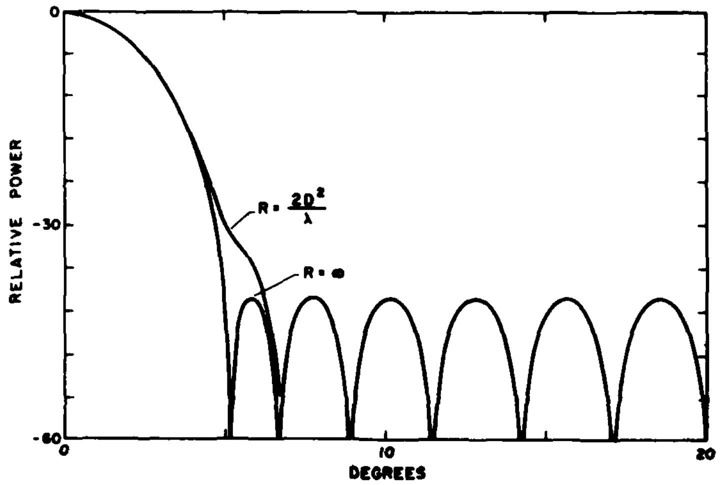


Figure 4. Farfield Approximation Error on Chebychev Array

pattern, but the low sidelobes of the error pattern have negligible effect on the measured pattern.

The SBR will have sidelobes even lower than the 40 dB Chebychev pattern. As a result, the first two sidelobes and nulls would be distorted if the separation distance was not great enough. A 100 λ diameter antenna at λ = .25 m has a $2D^2/\lambda$ separation distance of 5 km. This is a tremendous separation distance, yet the pattern would still be distorted similar to Figure 4.

Phase errors are not the only errors incurred in performing farfield measurements. The source antenna does not create a perfectly uniform amplitude taper across the test aperture. In addition to the quadratic phase error, the source antenna will also produce a nonuniform amplitude distribution across the aperture of the test antenna. The narrower the main beam of the source antenna, the more pronounced this amplitude taper becomes. Figure 5 illustrates this

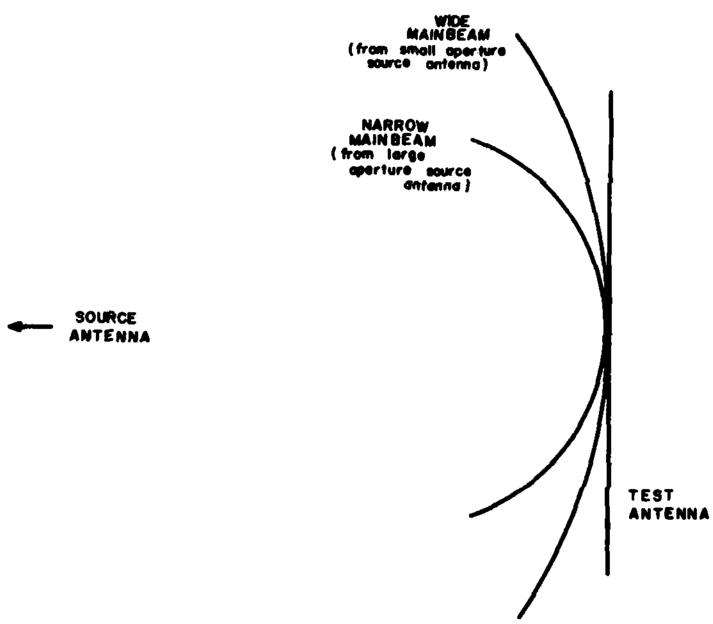


Figure 5. Test Aperture Illumination Error

point. The amplitude taper reduces the measured directivity of the test antenna. For instance, a source antenna that generates $\pm$ .15 dB amplitude taper across the test aperture of a 30-element 40 dB Taylor $\bar{n}$=6 reduces the measured

directivity from 23 dB to 22.88 dB. One's first impression might be to increase the distance between the source and test antennas, or use a source antenna with a broader beam. The first solution would not only decrease the error due to the amplitude taper, but it would also decrease the errors due to the quadratic phase term. The quadratic phase error has a more severe effect on the measurements than the amplitude taper error. In fact, the amplitude taper error has virtually no effect on the relative antenna pattern with amplitude tapers as high as 1 dB. Usually the phase error separation distance satisfies the requirement to minimize amplitude taper errors. Either method would be suitable if the antenna were being measured in an ideal environment.

In an ideal environment, the only energy illuminating the test antenna comes from the source antenna via a direct path. In real life, the energy from the source antenna main beam scatters off objects in the antenna range, and arrives by many indirect paths as well. Energy scattered from the ground can add appreciable errors to the measured pattern. It is highly desirable to prevent the energy in the main beam of the source antenna from scattering off the ground and illuminating the test aperture. One method of accomplishing this is to use a narrow beam source antenna and set the distance to allow only the sidelobe energy to be scattered from the ground. Ground reflections of the main beam will cause more problems when measuring a low sidelobe antenna than the amplitude taper associated with the narrow beam. Thus, the few tenths of a dB loss in directivity is worth the scattering suppression.

As one might suspect, the use of a highly directive source antenna adds yet another problem. To avoid an asymmetrical amplitude distribution at the aperture of the test antenna, the peak of the illuminating beam must be aligned with the center of the test aperture. Fortunately, this alignment problem is not too difficult to solve.

Another measurement error due to misalignment is a cosinusoidal phase error. This error occurs when the axis of rotation and the phase center of the test antenna are not aligned. The magnitude of this error is proportional to the alignment error.[1] Normally, the resulting measurement error can be reduced by careful adjustment of the axis of rotation. Unfortunately, moving the physically large and structurally weak space-based radar antenna would not be easy.

The degradation of the measured antenna pattern due to energy in the main beam of the source antenna being scattered by the ground was discussed earlier. Low sidelobe antenna measurements are also degraded by another scattering problem. Energy in the sidelobe region of the source antenna can reach the main beam of the test antenna through multipath. When the test antenna is being measured in its sidelobe region, this multipath energy can be the dominant contributor

1. IEEE Standard Test Procedures for Antennas (1979) The Institute of Electrical and Electronics, Inc., p. 73.

to the measured energy. In Figure 6, the loss associated with the direct path signal from the source antenna's main beam to the test antenna's sidelobe can be represented as

$$L(\Theta, \Phi) = \frac{P_T}{\frac{P_T}{4\pi R(\Theta,\Phi)} \; \frac{\lambda^2}{4\pi} \; G_r(\Theta) G_T(\Phi)} \qquad (6)$$

where

P_T	is the transmitted power
λ	is free space wavelength
$G_T(\Phi)$	is gain of source antenna in the direction relative to the main beam direction
$G_r(\Theta)$	is gain of receiving antenna in the Θ direction relative to the main beam direction being measured
$R(\Theta,\Phi)$	is the path length.

The loss incurred by the signal following the direct path from the source antenna's main beam to the test antenna's sidelobe can be written conveniently in decibels as

$$L_1 = 92 + 20 \log f + 20 \log R_1 - 10 \log G_r(\Theta_1) - 10 \log G_T(0) \qquad (7)$$

with

f = frequency in GHz.

The loss due to the reflected signal can be written in a similar form.

$$L_2 = 92 + 20 \log f + 20 \log R_2 - 10 \log G_r(0) - 10 \log G_T(\Theta_2) + 10 \log \alpha \qquad (8)$$

where α is the attenuation due to the cross section of the scatterer S. As an example, consider the case where

$G_r(\Theta_1) = -60$ dB

$G_T(\Theta_2) = -30$ dB

$R_2 = 10R_1$

$\alpha = 1$

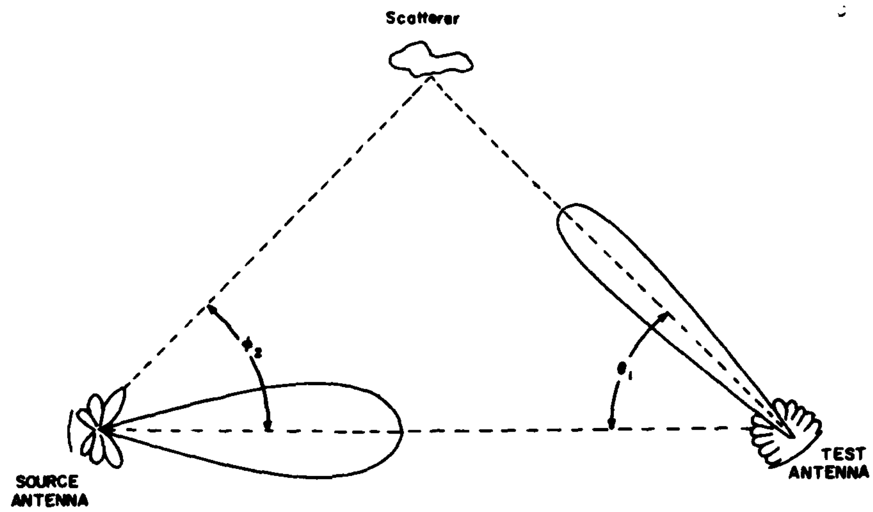


Figure 6. Scattering From the Environment

In this case, the energy received due to the reflected signal is 20 dB greater than that due to the direct path. Clearly, this is a serious error; however, these scattering errors can be reduced by rotating the test antenna in the elevation plane to keep the main beam directed away from scatterers on or near ground level. This approach appears impractical for the space-based radar antenna, again because of its structural weakness.

Gravity is not the only environmental factor affecting measurements of a large space-deployable low sidelobe antenna. The elements, in particular the wind, or even a slight breeze, will deform the structure, causing significant additional measurement errors. Rain, snow, and surface heat waves may add additional small errors, especially over large distances.

Another environmental problem is temperature. The environmental extremes in space cannot be simulated on the antenna measurement range. The temperature extremes would test the operational limits of the various antenna components when they function as a complete system. This important test can only be done once the antenna is in orbit. Until then, errors created by the temperature extremes are only predicted theoretically.

One way of avoiding many of the farfield errors is to measure the antenna pattern at a reduced distance. Normally, the reduced distance implies phase

and amplitude measurements. The measurements are taken in the radiating nearfield, a small distance from the antenna. The nearfield measurements eliminate some errors, but magnify and create new ones. These measurements are considerably more complicated and difficult than the farfield measurements.

5. BACKGROUND ON NEARFIELD MEASUREMENT

While farfield measurements simplified the testing of antennas by eliminating the requirement to know the phase, nonideal phase distributions were found to generate errors. Nearfield measurements, on the other hand, require no assumption about the phase distribution across the aperture. Thus, nearfield measurements are not as simplified as farfield measurements, and may be less attractive. There are, however, different advantages to be gained by nearfield type measurements.

Nearfield measurements do not measure the radiation pattern directly. Instead, the pattern is predicted from the knowledge of the transverse components of the vector fields over a well-defined surface. In fact, the continuous field distribution over the surface is not required. From the well-known sampling theorem, only samples of the field distribution are required. Unlike farfield measurements, the test antenna radiates and the auxiliary antenna, the receiving antenna or probe, samples the field. The sampled data are then processed to obtain an angular spectrum of waves in terms of basic functions that satisfy Maxwell's Equations on the measurement surface. As in the farfield case, nearfield data must be taken for two orthogonal polarizations.

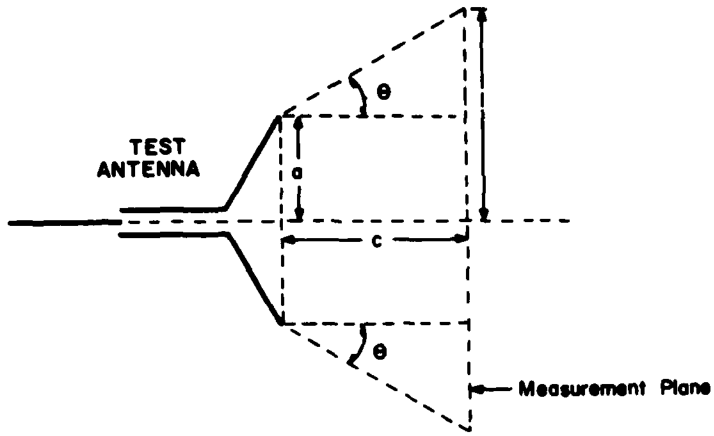
One of the more popular nearfield techniques is planar nearfield measurement. In this technique, the measurement surface is a plane parallel to the aperture of the test antenna, and the data is expanded as a superposition of plane waves. If the tangential components of the electric field E_t are known at every point on the plane defined by Z=c, then the field at any point P may be determined. This will be shown for the coordinate system of Figure 7.

The field on the Z=c plane can be expanded as a superposition of plane waves.

$$E(x,y,c) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \bar{A}\,(\bar{k})\; e^{-j\bar{k}\cdot\bar{r}}\; dk_x dk_y \qquad (9)$$

where

and $k^2 = \omega^2 \mu \epsilon$ for a lossless medium.



$$\theta = \mathrm{Tan}^{-1}\frac{l-a}{c}$$

Figure [illegible] Nearfield Error Due to Truncation of Measurement Plane

The amplitude function $\bar{A}$ is the plane wave spectrum of $\bar{E}$. Let $\bar{A}(\bar{k})$ be written as

$$\bar{A}(\bar{k}) = \bar{A}_t(\bar{k}) + \bar{A}_z(\bar{k}) \quad . \tag{10}$$

Where $\bar{A}_t(\bar{k})$ is the two-dimensional Fourier transform of $\bar{E}_t\,(x, y, c)$,

$$\bar{A}_t(\bar{k}) = \frac{e^{jk\cdot c}}{4\pi^2} \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \bar{E}_t\,(x, y, c)\, e^{j\,(k_x x + k_y y)}\, dx\, dy \tag{11}$$

In a charge-free region, $\bar{\nabla} \cdot \bar{E} = 0$, which in the transformed space becomes

$$\bar{k} \cdot \bar{A} = 0. \tag{12}$$

A_z can be expressed in terms of $\bar{k}$, and $\bar{A}_t$ is then

$$A_z(\bar{k}) = \frac{-1}{k_z}\ \bar{A}_t \cdot (\hat{k}_x \cdot \hat{k}_y) \quad . \tag{13}$$

The field at any point can then be determined from

$$\overline{E}(\overline{r}) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \overline{A}(\overline{k})\, e^{-j\overline{k}\cdot\overline{r}}\, dk_x dk_y. \tag{14}$$

The double integral in Eq. (14) can be difficult to evaluate in the general case. Fortunately, in the farfield the asymptotic value of the integral can be found using the method of stationary phase. For large r,

$$\overline{E}(\overline{r}) \approx j \frac{e^{-jk_o r}}{2\pi r} k_o \cos\theta\, \overline{A}\, (k_o \cos\varphi \sin\varphi,\ k_o \sin\varphi \sin\theta) \ . \tag{15}$$

Once $\overline{A}$ is known, therefore, the farfield can be specified completely.

In the planar nearfield technique, the integral for $\overline{A}_t$ is evaluated using a fast Fourier transform algorithm to process the sampled values of $\overline{E}_t$ on the measurement plane. A_z is subsequently determined from Eq. (13).

These methods can be extended to other measurement surfaces, in particular, cylindrical or spherical surfaces. The cylindrical waves are expressed in terms of complex exponential and Bessel functions, and the spherical waves are expressed in terms of associated Legendre function and spherical Bessel functions.

6. ERRORS IN NEARFIELD MEASUREMENT

Many sources of errors in farfield measurement are not present in nearfield measurement. Since both magnitude and phase measurements are made, the quadratic phase error due to the plane wave approximation is not present. This in itself makes nearfield techniques attractive when the pattern behavior in the region near the main beam is desired. In fact, if the integral in Eq. (11) could be evaluated accurately, nearfield measurement would be ideal.

Even though the digital computation can be performed with precision, there are still other errors generated. Some of these errors will be more severe with measurements in one coordinate system than in others, but the methods of error analysis can be extended from one coordinate system to another. Therefore, without a complete loss of generality one can restrict the analysis to the planar nearfield case.

To evaluate the two-dimensional Fourier transform accurately, one must know the magnitude and phase of the tangential E field at the observation points

in the Z=c plane. In practice, this is not possible. First the measurements must be limited to a truncated regionof the measurement plane. This restriction clearly will introduce errors in the farfield pattern. Additional errors will be generated because of the probe's inability to sample the field at a point. Even if this were possible, there would still be errors related to the inaccuracies of the probe placement.

The errors due to truncating the measurement plane are particularly important when the far out sidelobes are of interest. Reliable information about the radiation pattern can be obtained for only a small angular sector. Geometrical optics show this angular region, as shown in Figure 7, is determined by both the size of the scan plane, and its distance from the antenna aperture.

The probe antenna does not measure the field at a point. Instead, its output is a weighted average of the energy illuminating its aperture. In addition, the probe alters the measured field due to mutual coupling. The errors induced by the non-ideal probe can be reduced by compensating for its radiation pattern in the data reduction. The remaining probe errors are those that are due to the inaccuracies of probe placement.

In the planar-scan technique, the probe is moved in the plane described by Z=c. Position errors occur when the probe does not remain in that plane. Other errors occur due to inaccuracies of the probe position within the scan plane. Generally, the amplitude and phase vary slowly over most of the measurement plane. Thus, the most significant position errors are those that are due to longitudinal errors.

The dominant errors in the radiation pattern are determined by the displacement errors in the region where the phase variations are small. This is true even in the far out sidelobe, even though the field itself in the far out sidelobe is determined by the nearfields outside this region. Yaghjian[2] presents a simple expression for the upper bound of these errors.

This bound which holds for both random and systematic errors is

$$n(\bar{r}) \leq \left\{ \frac{a\lambda\Delta}{2\ell} + n_z \right\} \frac{g(\bar{r})}{2} \tag{16}$$

2. Yaghjian, A. D. (1975) Upper-Bound Errors in Farfield Antenna Parameters Determined From Planar Nearfield Measurements, NBS Technical Note 667, National Bureau of Standards.

where

α = weighting term, is a function of the aperture taper

λ = wavelength ℓ = maximum width of the antenna aperture

$\Delta = 2\pi \Delta P/\lambda$

ΔP = maximum amplitude of the transverse displacement errors

δ^2_{max}, sum pattern, $\theta < \lambda/10\ell$

$n_z = 8\Delta F \delta_{max}$, difference pattern, $\theta < \lambda/10\ell$

δ_{max}, sum and difference pattern, $\lambda/10\ell < \theta < \pi/2$

$\delta_{max} = 2\pi \Delta Z/\lambda$, ΔZ is maximum longitudinal displacement error

ΔF = Fractional difference between the amplitudes of the two main beams in the difference pattern

$g(\bar{r})$ = ratio of the amplitude of the maximum farfield intensity to the farfield intensity in the given direction

$n(\bar{r})$ = the fractional in the computer farfield .

The fractional error $n(\bar{r})$ is defined as

$$n(\bar{r}) \equiv \frac{|\bar{E} \pm \Delta\bar{E}| - |\bar{E}|}{|\bar{E}|} \leq \frac{|\Delta\bar{E}(\bar{r})|}{|\bar{E}(\mathbf{r})|}$$

with $\bar{E}$ being the error-free field and $\Delta\bar{E}$ the error field.

Neglecting the transverse displacement errors, a 3 dB error in the peak of a -40 dB sidelobe would allow an error in the longitudinal position of about 0.01 λ. Similarly, a 3 dB error in the depth of an 80 dB null would allow a maximum longitudinal error on the order of $10^{-6}\ \lambda$. While the position tolerance required for the sidelobe level is achievable, the more stringent requirement for the null depth is not.

Scattered energy is a significant problem in measuring low sidelobe and deep nulls on farfield ranges. It also proves to be a problem in measuring these same parameters on a nearfield range. As mentioned previously, the energy scattered from the probe disturbs the nearfield being measured. Other scattering objects in the nearfield environment also add errors. The probe positioner, for example, scatters energy, and the walls of the test chamber make the problem even worse.

Fortunately, absorber material can be used to reduce the effect of scattering. It is significantly more economical to use absorber material in the relatively small nearfield range than it is in the large farfield range. Absorber material alone,

however, will not reduce the scattered energy enough to measure accurately the low sidelobe levels and deep null depths required for the space-based radar antenna.

Another area of concern in farfield measurements of the space-based radar is the physical environment. Gravitational forces would deform the structure resulting in severe degradation of the pattern. While the gravity would have the same effect on nearfield measurements, it is possible to at least approximately account for its effect in the reduction of the nearfield data. The mechanical distortions are deterministic, and numerical computation is already required to perform the farfield transformation. The farfield for the deformed antenna, therefore, can be determined, which would give some confidence in the antenna's performance in a gravity-free environment. The deleterious effects of weather on the measurements would not be a problem, since the antenna could be enclosed in a controlled environment; however, it would still be impractical to test the antenna in the environment of the extreme temperature changes of space.

7. CONCLUSION

The SBR's antenna pattern is difficult to verify prior to launching the radar into space. The combination of low sidelobes, large aperture, and fragile structure in one antenna is a new concept. The low sidelobes require low errors in probe positioning, scattering, amplitude, and phase, etc. The large aperture and fragile structure require high measurement ranges and massive support structures. The required large antenna range and supports make the low error tolerances very difficult and expensive to meet.

The "Buck Rogers" antenna is becoming a reality. We must begin to think of how this new breed of antennas is to be tested prior to launch. The purpose of this report is to emphasize the importance and difficulties involved with measuring future SBRs. Perhaps the costs and problems of testing the antenna make antenna pattern measurements for SBRs unrealistic. The problem is new and needs a lot of thought and experimentation before an answer is evident.

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